THE MORTALITY

AFTER

OPERATIONS OF AMPUTATION

OF THE EXTREMITIES,

AND THE CAUSES OF THAT MORTALITY.

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TO HENRY LEE., ESQ., F.R.C.S., PRESIDENT,

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MEDICAL SOCIETY OF KING'S

COLLEGE, LONDON.

GENTLEMEN,

BEFORE you, to whom it was originally due, I lay this Essay in its present form. The encouragement and assistance that I received on the evening on which I read it before you determined me to endeavour to render it less incomplete than it was then.

Especially I have to thank Mr. Henry Lee for aid and advice, and Mr. George Lawson for the statistics with which he furnished me.

To others interested in this matter a few words of explanation concerning the subject, and apology concerning the author, are due. The Essay was originally written to compete for a Prize, the title having been chosen by the Dean of the Medical Department of King's College (Dr. Guy). Much has been added to it since. I have dared to differ in these pages from some high authorities; but I was convinced that the subject is very important, especially at the present time; and that, at least, an accumulation of data might facilitate the labours of more competent observers than my-

self. These are my excuses for my hardihood in publishing. There may be, too, something beneficial in truth being sought by one so young in the Professiona, untramelled by prejudice. I can easily conceive that, in the labours of the learned on this subject, pet theories may creep in—mingling even with STATISTICS,—though a would-be-vigilant watcher be over them. If I have erred it has not been thus. "Nihil est mihi veritatis luce dulcius."

THE AUTHOR.

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ON THE MORTALITY AFTER THE OPERATIONS OF AMPUTATION OF THE EXTREMITIES; AND ON THE CAUSES OF THAT MORTALITY.

Not only at the outset of an enquiry of this sort does it strike one as a difficult task lying before one—the assignment of true causes, the careful sifting of the apparent from the real, the explanation of discrepances, in that spirit of caution neeessary to those who are investigating the fore-ordained, complex influences which rule over human life—but the difficulty is increased at every farther step, for each becomes a yet new point of view, and discloses a yet wider field. I cannot hope to fulfil this task completely—the enquiry is not to be fully made by one man. It is only by accumulated experience, by careful record of observed facts, that deductions can be made; and theories from these have to be well weighed and have to pass through the sieve of many impartial minds. The portion of task that I allot myself is—to collect what I am able to do of the results obtained by men who, in various phases, have investigated this subject, or parts of this subject, before; and to strive myself to deduce somewhat from records I have been able to obtain. It is scarcely possible to divide the one part of this subject from the other; the general plan, then, to be adopted in these pages, is a clinical plan—such an one as he would adopt who would pass from step to step. First, the general subject of the rate of mortality will be undertaken; and subsequently the various special points which the general enquiry has suggested.

I.

Amputation, "the opprobrium of surgery," has ever been considered an operation not rashly to be performed—in early times one scarcely to be undertaken at all. We can well imagine how

the ancients, without sensible means of controlling hæmorrhage, and with an inrooted dread of its occurrence, shrank from an operation where bloodshed was so great. Accordingly, in the infancy of surgery, it was never performed. In the age of Hippocrates, whose, creed yet was, "Physic!—the Knife!—Fire!" the operation seems to have been confined to the removal of mortified parts. It was not until Celsus that there was any improvement; he extended slightly the list of circumstances under which the operation should be undertaken, and he distinctly specifies in his work a method of arresting hæmorrhage by ligatures on the bleeding artery. After him was an age of "Cimmerian gloom." We can easily realise how fatal the operation was then, and glory that we in this age neither are subject to the use of, nor employ, the red-hot knife, nor other potential-indeed, cautery.

Guido di Cauliaco (Gallice Guy de Chauliac), humanely encased the member whose removal was desired, in pitch-plaster, and, applying a tight band, allowed it to mortify off spontaneously. The invention of gunpowder, though it gave more opportunities for amputation, caused no improvement in our ancestors' practice, until came Ambrose Paré — thanks to him for the abandonment of the disgraceful styptics and caustics, and the adoption of Celsus' idea of ligature of bleeding arteries! Yet, of course, time elapsed before the ancient system was discontinued. In the middle of the 17th century, rose our own Wiseman. Amputation was divested by him of many of its terrors, and the mortality after it was lessened. In military practice he enforced primary (immediate) amputation, and surgeons began to disbelieve in the *peculiar* venom hitherto supposed to have existed in powder and ball. The essential steps of the operation now were (1) the application of a ligature around the limb about two inches above the point at which it was desired to amputate (2), drawing up the muscles and incising as far as the bone with a large curved knife, with the back of which the periosteum was scraped off, (3) the sawing through the bone and ligature of the arteries after the manner of Paré. After the operation, the cut muscles were drawn over the bone and fastened by stitches or bandage. Still, the wound was dressed with styptics. The circumstances adverse to the success of the operation now were (1) the size of the wound (so large a part of the stump being without a fleshy covering), and the consequent long and profuse suppuration, (2) the slowness of the stump to heal, (3) the exhaustion attendant, the ends of the bones being left projecting. About 1679, the idea of a flap occurred to Mr. Lowdham, of Exeter, and was put in practice by his brother, Mr. Yonge—its formation, its being adapted over the face of the stump and sewn by four or five stitches (in fact nearly as the operation is at present done) is described by the latter.

The next improvement was the use of the tourniquet in the operation. It now began quickly to assimilate that of our own day. Petit abolished the large crooked knives, and invented those of less terrific form now in use; yet Petit put too much confidence in pressure instead of ligature. Now were established the two ways of performing amputation—the circular method, *i.e.* the old operation, modified from time to time—and the newly-introduced flap. The former was practised and improved by Alanson; the latter received many improvements at the hands of Hey, Chopart, Dupuytren, Larrey, Lisfranc, and Liston.

Such then is a brief—not, history of amputation—but historical resumé of the most special circumstances affecting the increase or decrease of the rate of mortality after the operation.

We now come to the investigation of the question—What has been the fatality of the operation in late years? On this point, the results of observers are very conflicting; some, as I shall presently tell you, argue that the rate of mortality after the operation, has been increasing; others hold that it has been diminishing. To establish arguments on this question from statistics, we must, I think, allow one or two axioms. We must not expect absolute exactitude in our tables and judge that a solitary result will establish a truth. But when we take similar fields of observation, and periods of time nearly similar in their duration, our results at any rate establish a high degree of probability. The following tables have been compiled partly from Mr. Guthrie's commentaries, partly from the records of the London Medical Society of Observation, which, through the kindness of Mr. Henry Lee, I have been enabled to consult; and partly from the records, so valuable because so circumstantial, of individual operations, published periodically in the "Medical Times and Gazette." I must say a word or two as to the manner in which the results in the latter case were arrived at. Before I had finished the compilation from the papers, Mr. Teale, of Leeds, in his work on Amputation, came to my aid. From this latter I obtained the result of thigh and leg amputations, to which, each year, I added those of the upper extremity, obtained from the "Medical Times." From his results, Mr. Teale strikes out the cases which are "under treatment." I cannot consider this quite just; the error, whether they be retained or ignored, will certainly be small; but the probability, I think, is far greater that these have recovered than that they have been unsuccessful. Especially for this reason: that one sees recorded in the "Medical Times" report, occasionally, that the case "So and So reported as under treatment has died." Evidently a supervision has been exercised over these cases.

In these tables the cases "under treatment," unless other-

wise indicated, have been added to the list of recoveries. The proportion of "cases under treatment," to the whole number of amputations, is about one in thirteen: so anyone differing from me in my opinion as to the favourable issue of these, may, with ease and very near correctness, alter my results. This must not be done in the case of the operations from 1837 to 1842, for in those records every case is given with its absolute result. Concerning these tables I shall have more to say under the head of Anæsthesia. The results of amputation during the latter part of the Crimean war, were shown me by Mr. Lawson.

TABLE I.

Mortality in Military Practice.

	Mortality, per cent.
Army in Spain, both in hospital & field (principal amputations only)	44
Army in Crimea during the late Russian War (all amputations)	27·3

TABLE II.

During the Great Paris Insurrection.

Hospital.	No. of Operations.	Deaths.	Per Cent.
La Charité ..	26	10	38
St. Louis	12	7	58
———	52	20	38
Hotel Dieu ..	15	9	68
Various others	79	50	63
Average			52

TABLE III.

In London: 1837 *to* 1857.

Period, &c.	No. of Operations.	Deaths.	Per Cent.
1837-1842	184	69	32·95
1840.....	87	32	36·07
1854.....	180	56	31·11
1855.....	136	35	25·75
1856.....	155	43	27·74
First six months of 1857	84	19	22·61
Jan., 1854, to June, 1857	555	153	27·05

These tables show that in time of war we must expect to lose nearly half the number of those soldiers whose wounds have necessitated amputation, and that in our own hospital practice, about one out of three cases. I shall again allude to these points at a future stage.

Is the operation of amputation, *cæteris paribus*, followed by a greater rate of mortality than other capital operations? According to the following table, it would appear that the operation for the cure of strangulated hernia is more fatal than amputation, while the latter is attended with much greater mortality than lithotomy.

TABLE IV.

Comparative Mortality after Capital Operations. Mortality in London Compared with that in the Provinces.

	Amputation.	Lithotomy.	Herniotomy.
London Practice, 1837-42	31·7	..	50
„ „ 1856	27·74	26·6	47·78
Provincial „ „	26·15	12·34	27·17

One cannot fail here to be struck with the decided success of the Provincial over the London practice. No doubt this cannot be taken as the absolute expression of the value of the former above the latter, but its comparative success is beyond a doubt. According to Mr. Teale, it would be about one and a half per cent. more favourable in the case of amputation of the thigh and leg.

The cases coming under the treatment of London surgeons are, most probably, those of patients more debilitated than such as require amputation in the country. But this seems not to be all—the depressing atmosphere of a London hospital must have its share. This is full of significance. How desirable it would be to have a hospital for patients requiring formidable operations within an easy distance of London, with the advantage of London skill, and with the no less important advantage of country air!

Concerning the relations between amputations and EXCISIONS, a careful enquiry made by Mr. Thornton, whose observations embraced 1154 cases occurring in the army service, shows that excisions are more favourable by three per cent. (see "Ranking's Abstract," vol. xxv. p. 150). I imagined, *à priori*, that this, as a general average, must be too low, for cases of excision are less favourable in military practice than in civil. Statistics bear out my hypothesis. In 1855, 1856, and the first half of 1857, there have been performed 69 excisions of the principal joints—the deaths have been 13—thus making a mortality of 18·84 per cent. Compare this with the mortality after amputation; it is about half as favourable again. Citing the cases of individual joints, Mr. Thornton states that excisions of the shoulder are 15 per cent. better than amputations, and, of the elbow, 7·19 per cent.

It would, on first thought, appear probable that the mortality

after the removal of the lower extremity—the greater mass—should be greater than that after amputation of the upper extremity; and so it is—but the mortality after the removal of the several parts varies eonsiderably.

TABLE V.—A.

*Comparative Mortality after Amputation of the Several Members.**

	* Military.	Ditto, Mr. Thornton.	1840.	1856. London	1856. Provincial.	Average
Shoulder Joint....	46	31·66	..	..	..	38·88
Arm.....	34	..	23·8	21·4	16·1	23·8
Forearm						
Thigh	52	..	40·7	28·3	30	33 } 41·1
Leg			41	33·3	30	34 }

Aecording to these results the mortality after removal of the upper extremities is somewhat more than half as great as amputation of the lower. Amputation of the forearm seems to be about half as fatal as amputation of the upper arm. In a table given in the late Mr. Guthrie's work, (p. 154)—a table which, however, ean only be taken as an approximation to the truth, sinee eases diseharged elsewhere are counted as sueeessful, and many eases are exeluded—the mortality in the former ease is to that in the latter as 25 to 9.

I am mueh indebted to Mr. George Lawson for the results of the amputations during the latter part of the Crimean war, with which he has furnished me. I append them in a separate table.

TABLE V.—B.

Mortality during the latter half of the Crimean Campaign.

	No. of Operations.	Deaths.	Per Cent.
Hip	7	7	100·0
Thigh { upper third....	38	31	86·8
Thigh { middle.....	56	31	55·3
Thigh { lower	46	23	50·0
Leg	89	28	30·3
Ankle-joint	9	2	22·2
Medio-Tarsus.....	7	1	14·2

* Calculated from the late Mr. Guthrie's Commentaries, pp. 151, 152. It includes the operations in the Spanish eampaign between 21st of June and 24th of December, 1813, both in Hospital and on the field. Cases "under treatment" have been deducted.

The results in the third column, as Mr. Lawson has pointed out, strangely show how the mortality was dependent on the amount of limb removed. But that this is not the general rule is seen by Table v. A, wherein the mortality after leg amputations in one case is equal with, and in some cases exceeds, that after thigh amputations.

Scattered throughout the items of general medical information in the medical papers, we often see an account of isolated successful cases of amputation at the *hip-joint*. The danger is, that amid this blazon of success the admonitory voice of failures should be unheeded. Mr. Thornton, before quoted, states, that, of 10 amputations observed by him, all were fatal. So also were all those recorded during the Crimean war, (Table v., B.) M. Heyfelder, (Gaz. Med. de Paris, Nov. 3rd, 1854) performed the operation five times, with success in three instances. To refer to older authorities, Cooper says:—"A calculation has been made that the proportion of recoveries has been six in twenty operations. At all events, it appears that, in the course of ten years, nearly twenty well-authenticated instances of recovery after this severe operation have occurred." The operation has been scarcely more successful of late years; primary amputations seem to be almost all unsuccessful.* Mr. Thornton's cases were probably all primary. I have records of primary operations by Mr. Erichsen and Dr. Beatson, still unsuccessful—the former operated on a thigh crushed by a cart-wheel: the patient died from shock; the latter for a gun-shot wound in the left hip by which the neck of the femur was completely comminuted. In this case also the patient died of shock; whilst, on the other hand, M. Heyfelder's operations were all for disease. One case of primary amputation was successfully performed by Mr. Humphreys, of Addenbrooke's Hospital, at Cambridge. The case was a compound fracture of the thigh by a waggon-wheel; no fewer than 43 ligatures were applied. Another case of amputation for *disease* was performed by this gentleman with success; it was for epithelial cancer, the size of a cheese-plate, on the outer side of the left thigh. Another example of success in a pathological amputation of the hip is recorded by M. Hénot, of Metz; the operation was undertaken on account of a large exostosis.

II.

Pursuing now the clinical way in which I proposed to consider this subject, let us suppose that we are debating as to the propriety of an amputation on our unfortunate patient. The first

* Blandin and Larrey had one successful case each out of three and seven.

question to be considered is, whether injury or disease is supposed to neeessitate the operation. We thus divide amputations into two great classes—amputations for injuries and amputations for disease. The former are nearly twiee as fatal as the latter. Operations for injury are capable of further sub-division aeeording to the period of their performance. After an aeeident a previously healthy man will suffer at first no more than the effect (primary) of that aecident on his nervous system; there is no change in the appearance of the wounds. After a day or two the seat of injury will have become acutely inflamed, fever will be induced, suppuration will oecur. Still uninterfered with, the suppuration continues, sloughing probably occurs, and hectie fever—meanwhile, the patient is wasting—sets in. The first period, then, is the period of nervous tension ; amputation done during this time is called *primary*—the seeond is the period of inflammatory fever. Amputation now done is called intermediary. The third, the period of hectic, is that of secondary amputation. This is Mr. Alcock's division, but hitherto, primary and secondary operations only have been recognized—the latter having been defined by Mr. Guthrie as "Amputations after the lapse of six or more weeks ; when suppuration is fully established." There has been mueh discrepaney of opinion as to the comparative suceess of operations done at these two periods. The authority last quoted says that primary operations have a great advantage. "In the seeondary period after injuries, the areolar and museular textures near the part injured are often unhealthy : the bones are in many instances inflamed internally, and their periosteal membranes deposit on the surrounding parts so much new ossific matter as frequently to envelope in a few days the ligatures on the vessels and render them immoveable, neerosis of the extremity of the bone following as a neeessary consequenee, and protraeting the case for months."

Mr. Guthrie's assertion is fully borne out by the events of the Crimean war. Of 690 primary amputations 175 were fatal—viz., 25·3 per cent: whilst of 89 seeondary amputations, 38 were fatal, representing a mortality of 42·7 per cent.

The great cause of death after these operations is the impression on the nervous system. Either the impression is sueh that the patient never rallies—he dies of *shock* within 24 or 36 hours ; or he lingers, sinking gradually during several days ; dies of *exhaustion*. This, however, is not the sole eause ; patients often die of those more lingering affections presently to be discussed.

But our patient is afflicted not suddenly by the wheel or the eannon-ball, but, Philoetetes-like, *νόσῳ διάβόρῳ*. The cases most frequently neeessitating amputation are those of *diseased joints*.

These have been, happily, as may be seen by the following table, of late years comparatively little fatal. Mr. Hussey says of 164 cases observed by him in the Radcliffe Infirmary, Oxford, 91 were for diseases of joints. Of 55 of these in the thigh, ten were fatal; 6 died from the effects of the operation, and 4 did not recover sufficiently to be sent home. Of 20 in the leg, one died; of 6 in the upper arm and 10 in the forearm, all recovered. The mortality, he says, is not affected by the duration of the disease, nor by the extent of disorganization of the joint. The table (VI.) has been compiled by myself from the records of single operations published from time to time in the "Medical Times." The observations extend over the whole of 1856, and the first six months of 1857. I have only here recorded the more ordinary affections for which amputation was performed; but hope I have omitted nothing of interest:—

TABLE VI.

Mortality after Amputations for Injuries and Special Diseases.

Seat. Nature of Disease, &c.	No.	Recoveries.	Deaths.	Causes of Death.
THIGH,				
Diseased Knee Joint....	54	45	9	Pyæmia, 5 Collapse, 2 Exhaustion, 1 Tetanus, 1
Primary Amputation ..	15	6	9	Exhaustion, 4 Pyæmia, 3 Shock, 2
Sloughing after Phlegmon (Of 3 operations for gangrene, all were successful.)	2	2	0	
LEG.				
Diseased Ankle-Joint & Diseased Bones.....	19	17	2	Exhaustion, 2
Primary Amputations ..	16	11	5	Pyæmia, 4 Exhaustion, 1
Phlegmonous Erysip. ..	3	1	2	Exhaustion, 2
UPPER EXTREMITY.				
Diseased Bones and Joints	13	13	0	
Primary Amputations ..	21	18	3	Shock, 1 Pyæmia, 2
Secondary ,, ..	2	1	1	Exhaustion, 1
Phlegmonous Erysip. ..	3	0	3	Shock, 2 Exhaustion, 1

An interesting comparison may be made between this table and the following.

TABLE VI.—B.

Mortality during 1837-42.

Injury or Disease.	Upper Extremity.		Thigh.		Leg.	
	No.	Deaths.	No.	Deaths.	No.	Deaths.
Injury	10	2	4	3	8	4
Compound Fracture....	10	3	8	4	20	6
Diseased bones and joints	17	4	41	12	29	13
Mortification	9	3	5	3	9	3

From this it appears that the operation during the years mentioned was attended with great fatality in the cases of diseased bones and joints; whilst the former table would lead to the supposition that in late years the hazard in these cases has been remarkably diminished. This will engage our serious attention at a future stage. I would here call attention to the great rate of mortality attendant on the operation in the case of Phlegmonous Erysipelas. In all the records I have consulted, I have only seen account of one or two cases successful. Amputation seems to be much more successful when the disease has proceeded to sloughing.

Having now considered the nature of the injury which our patient has suffered, or the disease of which he has been the subject, and having had due regard to his general condition, that his physical powers are great enough to combat with this severe operation, we come to the performance of the operation itself. But first comes the question of

ANÆSTHESIA.—When we are possessed of an agent capable of rendering our patient wholly insensible to the pain of this formidable operation, and apparently exerting no ulterior ill-effect on his system, it seems strange that we should hesitate to avail ourselves of it. We have such an agent in chloroform. And it would seem probable that since its introduction, when the operation ceased to influence the sentient part of the nervous system, when the patient debilitated may-be, or having acute sensibilities, was brought to the level of the robust and plethoric, the mortality after it should be lessened. Accordingly, after the anæsthetic had been tried for some time, Dr. Simpson published some tables whereby it was shown that whilst the average mortality before etherization was 29 per cent., it fell to 23 per cent. after its introduction. Dr. Snow, too, published other statistics, wherein, however, he made the general mortality after anæsthesia higher—viz., 27per cent.—still an evidence of the value of chloroform. Few would be inclined to call in question results which so well

harmonized with their foregone eonclusions and their sympathies. But in the "Medical Times," of Oetober 25th, and November 1st, 1856, Dr. Arnott published a paper wherein he (1) declared that the mortality after amputation had inereased sinee the introduetion of chloroform, and (2) attributed that inerease to the influenee of the anæsthetie. He argued against Dr. Simpson's tables, in that they eontained observations spread over unequal times in different hospitals, and in their not giving the charaeter of the eases—and against Dr. Snow's, because they were met with in private practiee, and he deemed that there was seleetion in the eases. The mortality before etherization in certain London hospitals —viz., University College, St. Thomas's, and Bartholomew's— (equal periods of observation being taken) Dr. Arnott states to be 20 per eent.—whilst after its introduetion—viz., from July, 1853, to June, 1856—it was 34·4. Whilst before etherization the total number of cases observed was 174, afterwards it was 430. In the Provineial hospitals, the mortality formerly was 15 per eent.—the average in 2 years and 9 months, from November 1856, 30 in 100.

In the ease of army praetiee, Dr. Arnott's views are supported by Dr. Gordon (in a report read before the Crimean Medieal Soeiety), and by Dr. Mowatt. The latter gentleman states (speaking of operations done under the influenee of ehloroform): "In some eases, reaetion is never thoroughly established, the desire for food never returns, and the patient sinks as it were steadily, and dies from exhaustion in 12-24 hours. These eases are far more numerous than is generally supposed, and many of them may be fairly termed deaths from ehloroform, but are never so returned."

Mr. Holmes brought to bear on the subjeet the statisties of St. George's Hospital, and showed the eonverse to Dr. Arnott. Previously, for four years, to the introduetion of ehloroform at this hospital, the mortality from pyæmia had been 5·25 per annum. latterly (*i.e.* for the ten years subsequent) it had been 4·79 per annum. Many arguments *pro* and *con* were addueed by these authorities. Dr. Arnott still insisted that the inerease in the mortality after amputation sinee the introduetion of chloroform was respeetively in four London hospitals 10·9, 10, 12·5, and 17·6; whilst the provineial average inerease was 12·5, per eent. Dr. Fenwick objected that Dr. Arnott's observations embraeed different periods at different hospitals. He eonfined his observations to one, —viz. the Neweastle Infirmary, and eoneluded generally on the deerease of mortality sinee the introduetion of chloroform. The danger from shoek, he says, is lessened in the ease of traumatie amputations, and altogether lost in the ease of operations for disease. The only exceptions to the general rule of the decrease of the mortality after amputation sinee the use of chloroform, were

in cases of traumatic amputations of the leg and pathological amputations of the arm. Only two cases of the latter were observed, so they may be thrown out of the scale on the ground of their being insufficient evidence. The excess in the former case was 5 per cent. Dr. Arnott replied to this, urging the insufficiency of the records.

Since Dr. Arnott's were the tables which apparently furnished the best established record of cases of amputation in the London hospitals, prior to the introduction of chloroform, I felt bound to receive deductions from them as the general expression of the truth—*i.e.* the truth as to the increase of the mortality since the practice of anæsthesia. The next question that arose was—Is this the relation of cause and effect? Deaths from chloroform—recognized deaths—are incontrovertibly rare. Such, also, usually occur in instances of the most trivial operations, and do not come within the scope of our subject. It must, I think, be allowed that chloroform, administered duly diluted with atmospheric air, and by those who know that they are dealing with an agent capable of inducing palsy of the heart or suffocation, is comparatively harmless in its *evident* results. The only case in which it may act prejudicially, is by its encouraging morbid phenomena.

Dr. Fenwick has remarked that limbs are now saved which, long ago, would have been sacrificed without the smallest hesitation. Undoubtedly, the surgeon in times past would have preferred, for the patient's safety and his own convenience, an amputation to a protracted operation for the removal of diseased bone—now, too, especially, the growing practice of resection of joints restricts the operation of amputation to the most unfavourable cases.

These are circumstances which would, without doubt, tend to exalt the rate of mortality after the operation. Still, I did not deem them of sufficient magnitude to account for the great increase which Dr. Arnott adduces in his tables. I was induced to search further. The first question was, of course, the correctness of the first hypothesis—that the general rate of mortality before anæsthesia was about 20 per cent. Searching for data, I was told that there were deposited with the Medico Chirurgical Society, records by the *London Medical Society of Observation* of the principal operations. Through the kindness of Mr. Henry Lee, I was enabled to consult this volume which contains records of amputations performed in all the principal London hospitals. I found these to be most complete and circumstantial—the patient's name, the kind of operation performed, the cause of amputation, the result, the period before recovery, or death, &c., being distinctly stated. The observations extended from 1837 to 1841. But, though the periods of observation seemed to be the same in the different hospitals, yet in some of these years fewer operations

were recorded than in others. To avoid this objection, I eliminated the records for the year 1840, wherein a large number of cases were observed, and dates follow each other with great regularity. This, surely, must be an approximation as near as possible to the truth. For the results, I refer the reader to table III.; therein it will be seen how much greater than 20 per cent. was the mortality in 1837-42, and how still greater in the year I had selected for the sake of greater correctness, 1840.

For the years subsequent to the introduction of chloroform, I consulted the record of operations, published periodically in the "Medical Times and Gazette."

But this is a question of very high importance, and I have thought it well to consult further for argument. I must beg attention to table V. A. which shows the comparative mortality after the several members. In every case the mortality since the introduction of chloroform has been diminished. I have included in the table only the results of the year 1856, as a type of the period subsequent to anæsthesia. But, in 1855,

of amputation of the thigh, 16 died out of 69=23 per cent.
of „ „ „ leg, 14 „ „ 39=35 „
„ „ „ „ arm, 5 „ „ 29=17 „

In the first half of 1857,

of amputation of the thigh, 10 died out of 36=27 per cent.
„ „ „ „ leg, 3 „ „ „ 24=12·5 „
„ „ „ „ arm, 6 „ „ „ 23=26 „

We will next investigate the mortality in reference to the cause of amputation. First, in regard to traumatic amputations. In earlier times these have been very fatal—so fatal, those of the thigh, that during war they have been by authority interdicted altogether.

Compare with the first column of table V. A., the following :—

TABLE VII.

Traumatic Amputations.

	Crimean War.	1837-42.	Jan., 1856, to July, 1857.
All Amputations.....	27·3	37	33
Thigh.....	64	58	60
Leg.....	30·3	35	31

The first item of this table must not be taken as evidence, because in the Crimean results are recorded amputations of the

tarsus and fingers, which are not in the others. Apparently, however, in civil practice, the rate of mortality in traumatic amputations of the chief members, has decreased 4 per cent. But in amputations of the thigh and leg, taken collectively, a striking similitude is observed in the results; whilst the mortality from thigh amputations seem to have slightly increased. This seemed to me to be the most doubtful point in the whole investigation—viz., whether in cases of severe accident operations should be done under chloroform. Men in robust health are not so well calculated to withstand the accumulated shock of a severe injury and a severe operation, as those whose powers of life have, as it were, gradually submitted themselves to the dominion of disease, and who are struck but by one *sudden* blow—the operation. The question that arises is—"Is chloroform an ulterior depressant?" Does it, after all its apparent effects have passed off, exercise a depressant influence which the feeble powers of life are sometimes unable to countervail? In order to bring some evidence to bear on this question, I performed some experiments on animals, which, though far from being conclusive evidence, may yet be not entirely without value.

Having taken a pair of white mice, apparently similar in point of nutrition, I divided, with a fine flat needle, their spinal cords, a finger's breadth above the pelvis, so as to produce complete paralysis of the posterior extremities. One of these was allowed to remain in the air, the other was placed under a glass jar of 180 cub. in. capacity. Through a tube entering this jar, 4 grains of chloroform were introduced and allowed to fall on a piece of blotting-paper suspended therein. (This is the proportion which, according to Dr. Snow, will fully produce the third degree of anæsthesia). After having been allowed to remain in the jar five or six minutes, the mouse was taken out and placed in favourable circumstances for its recovery.

The period of the death of each of these mice was noted. To similar operations and similar treatment, other mice were subjected.

The following were the results.

DURATION OF LIFE IN WHITE MICE AFTER DIVISION OF THE SPINAL CORD.

	Chloroformed.		Not chloroformed.	
A	4 hours, 33½ minutes.	B	25 hours, 1 minute.	
C	4½ ,,	D	23 ,, 47 ,,	
E	17 ,, 48 ,,	F	,, 10 ,,	
G	26 ,, 25 ,,	H	21 ,, 32 ,,	
I	21 ,, 54 ,,	K	22 ,, 42 ,,	

The average duration of life, then, in those placed under the influence of chloroform, was 14 hours and 9 minutes; whilst, in

the others, it was 18 hours and 38 minutes. The mouse A was the most injured by the operation. C died whilst under the influence of chloroform. If anything can be deduced from these experiments, therefore, it is that chloroform has some slight depressing action in cases of severe injuries, shortening the expectation of life.

We next come to the influence of chloroform on the results of pathological amputations, and here, apparently, there is happily no room for doubt.

In cases of diseased bones and joints, the mortality after amputation, as deduced from the tables of the London Medical Society of Observation, from 1837 to 1842—prior to the advent of chloroform—was 33 per cent. The mortality, as deduced from table II., in 1856, and the first half of 1857, was 12·9.

In cases of *thigh* amputation in the former case, it was 50 per cent.—in the latter, 16·9.

In *leg* amputations, 29·2 in the former case, 10·5 in the latter.

In *arm* amputations, 44·8 in the former; in the latter table no death is recorded.

This evidence seems overwhelming. It seems to show that not only chloroform does not exert a baneful influence on patient's submitting to chloroform, but that it exerts an influence to the preservation of life.

Since it might be objected that in the period adduced the mortality chanced to be unusually low, I have also investigated the mortality in cases of amputation for diseased bones and joints, in the years 1854 and 1855. In these instances, of 103 amputations of the thigh, 21 died—mortality 20·3 per cent.; of 35 of those of the leg, 8 died—mortality 22·8 per cent.; of 12 arm amputations, 1 died. Thus, though these numbers show a higher rate of mortality than those previously cited, they yet most distinctly favour the conviction that the mortality, in cases of amputation for diseases of bone and joints, has greatly decreased.

From all these observations on the subject of the influence of anæsthesia on the results of amputations, I am led to the conclusion that in cases of disease wherein amputation is necessitated, confidence in chloroform should remain unshaken; but that in cases of severe injuries it behoves at least to ponder well before its use. It seems to me, that in this case, the humanity which would urge the sparing of suffering would regret but little, the withholding of the anæsthetic agent here; for the sudden shock to the nervous system has already to some extent blunted the sensibilities, and rendered less poignant impressions of pain.

We now come to the consideration of the operation itself.

I shall attempt no comparison of the results of *flap* compared with *circular* operations, but regard the question whether the

former or the latter be employed as a pure matter of convenience. As Mr. Fergusson remarks, "It is indeed difficult to imagine why the circular incisions should cause all the above troublesome results (viz. non-union, suppuration, protrusion of bone, exfoliation, tumours on the end of bones, and so forth), whilst the flap method should avoid them." Only the circular, our Professor considers, a more difficult operation, "or, at all events, there is greater chance of a mistake occurring in the one than in the other."

Here it behoves me to speak of a new method of amputation, recently introduced by Mr. Teale, of Leeds. It nearly concerns our subject, for Mr. Teale proposes it "in the hope of somewhat diminishing the mortality of the operation."

The principle of the operation, which is designated "Amputation by a Long and a Short Rectangular Flap" is this: (1) to form an anterior flap, of length and breadth each equal to half the circumference of the limb, consisting of such parts as do not contain the large nerves and blood-vessels—(2) to form a posterior flap, containing the principal vessels and nerves of which the length is one-fourth that of the former flap—(3) the bone being sawn through, to unite the angles of these flaps by sutures, and to retain their surfaces in contiguity by other sutures.*

The chief advantages of this operation are, according to Mr. Teale, these—1st, the avoidance of tension—no strappings, "*no dressings whatever*" are required; the first flap is amply long enough to cover the bone and to compensate for the shrinking of the short flap.—2nd, the end of the bone covered by muscle and skin, but *not* by large nerves.—3rd, non-disturbance of the plastic process—the long flap soon becomes united with the severed bone, thereby the open veins of the latter are, at an early period, closed; the large nerves in the short flap being undisturbed, have a good opportunity also to become quickly permanently closed, and so incapable of imbibing putrid matter.—4th, the free outlet provided for purulent and other discharges through the favourable position of the incisions. Fifty-six amputations performed in this manner are circumstantially recorded in Mr. Teale's work. Death occurred in only seven instances, thus the mortality was only 12·2 per cent. In amputations of the thigh and leg for disease, the numbers are nearly large enough to admit of comparison with those done by the old-established methods in London and Provincial practice. In amputations of the thigh (taking 17 cases) the mortality is 17·5 per cent. In amputations of the leg (taking 27 cases) 3·7 per cent.

These numbers contrast very favourably with all other statistics

* "On Amputation by a Long and Short Rectangular Flap," by Thomas P. Teale, F.L.S., F.R.C.S. London: Churchill.

of amputation. Of course they cannot yet be taken as the absolute expression of the advantage of this operation. All these points, however, lead to the hope of their commencing a brighter page in the annals of amputation. Looking at it in the light of its convenience, we are attracted to it by its preserving the nerves from injury in their normal relative positions, and hence, probably, preventing those painful, though not evidently fatal, sequelæ of amputation dependent on nervous irritation or empaction, as well as by its protection of the bone, which has often undergone, and sometimes, too, now undergoes unhealthy change. And in the intenser light of its influence as regards life and death, probabilities seem to lean towards it. I may hope that in some future time, one worthier than I may read an essay before you on this subject, showing that the operation has lost that great fatality which I am obliged to show you it at present bears.

III.

The operation performed, we patiently await the result. Of the chances of the patient's recovery or death enough has been said already. How long before the one or the other ensues is the next question. I have deduced the following from the records of the London Medical Society of Observation:—

Average Periods of Recovery and Death.

	Recovery.	Death.
Thigh	58 days.	16·6 days.
Traumatic . . .	93	11·2
For diseased bones, &c.	48	20·2
Leg	77	14·8
Traumatic . . .	84	12·5
Diseased bones . .	42	19·2
Arm	67	11·7
Traumatic . . .	66	15·3
Diseased bones . .	110	10

It is strange that in the case of amputation of the upper extremity, the recovery should be more tardy and the advent of death more rapid than in the other cases. It is strange also that the same should be the case in pathological compared with traumatic amputations of that member.

Not the least interesting point in this enquiry is the consideration of the Immediate Causes of Death after Amputation. These causes are many, but the most frequent and the most

important range themselves under but few heads. It will not be attempted here to give a clinical history of each of the causes of death after amputation; but to consider them especially as influencing the rate of mortality. The following table includes all the cases (except those the termination of which is not mentioned) recorded in the London hospitals from January 1856 to June 1857.)

Table VII.

Seat.	No. of Cases.	No. of Deaths.	Causes of Death.
Hip joint	3	1	Secondary hæmorrhage
Thigh ..	106	33	Exhaustion, 17
			Pyæmia, 10
			Shock, 3
			Secondary hæmorrhage, 1
			Tetanus, 1
			Sloughing stump, 1
Leg	49	17	Pyæmia, 9
			Exhaustion, 7
			Pneumonia, 1
Upper extremity..	60	15	Exhaustion, 8
			Shock, 3
			Pleuro-pneumonia, 1
			Cause unmentioned, 1

Hence it appears that the two most common causes of death after amputation are—(1) shock and exhaustion, (2) pyæmia—that the former is now-a-days the most frequent, being twice as frequent as the latter.*

Shock and Exhaustion.—I have before spoken of the primary effect of amputation on the nervous system of some patients; a depression of the vital powers ending only in their extinction. Such may happen very early: the patient may succumb within twenty-four hours, the impression being lasting and unremitting. This unremitting form may justly be termed shock. Or the morbific influence may have an effect not so rapid; may have many a struggle with the powers of life; and by retarding the processes for repair, and encouraging morbid phenomena, gradually weary out the system. Death, in these cases, may occur in from days to weeks after the amputation. In shock, besides the nervous depression, secondary effects occur on the vascular system, a rapid, fluttering, feeble pulse; on the respiratory function, laboured and sighing breathing.

* Taking the period from 1854 to 1857, the mortality from shock and exhaustion, compared with that from pyæmia, is 51·2 to 32·7

The eyes stare listlessly, the face has a blank expression (if such term be allowable) the cerebral functions become more and more imperfect, the heart's pulsations cease, and death ensues.

A healthy man undergoing primary amputation is more likely to die from shock or exhaustion than a patient enfeebled by disease undergoing a pathological amputation. These effects are, as a rule, most frequent in cases of the most severe operations. Hence, they are most commonly developed after amputation of the thigh. The upper extremity seems to come next in point of frequency. As might be supposed, after *primary* amputation of the thigh, they are of *most* frequent occurrence. Thus, as shown by Table VI., in cases of this operation the frequency of cases of death from shock was 2 in 9 deaths, and from exhaustion 4 in 9—whilst in the case of amputation for disease of the knee-joint, there were, in 9 deaths, 2 registered shock and 1 exhaustion. Mr. James, of Exeter, thinks that the amputation being done through injured parts is almost the sole cause of the mortality after primary thigh-amputations. "Though," says this author, "the immediate effects of shock may have passed off an impression is made on the system, rendering it more liable to secondary inflammations and suppurations, and an impression is made on the blood, rendering it unfit for the reparative process." "To these are due many of the phenomena usually attributed to the imbibition of a septic principle, or to the effects of vitiated air."

Pyæmia.—This fearful and intractable affection is well known to cause a large proportion of the deaths from this and other severe operations. There is not space for the record here of various writers' opinions on this malady. I shall hope for pardon, therefore, for anything I may say dogmatically.

Whilst suppuration is occurring, if the patient have one or two distinct rigors, pyæmia is to be feared. If, in addition, diarrhœa occurs, great prostration, bluish or yellowish hue of the skin, delirium or stupor, laborious breathing, quick and small pulse, swelling about the joints, excessively painful—pyæmia, for certain, exists. Very frequently, the lungs are affected—inflamed, and infiltrated with pus.

To account for these effects, many theories have been advanced—they resolve themselves, however, into this general fact; that they are produced by a *blood poison*. It has been thought generally that they were due to the admixture of pus or putrid matter with the blood. From the present state of the question, it would appear most probable that they are due to the influence of a peculiar animal poison.—(For an excellent account of the theories that have been proposed, I beg to refer the reader to Dr. Hughes Bennett's Clinical Lectures, 2nd Ed. p. 849). Whatever be the physical nature of the poison, the system tries to eliminate it. This elimi-

ination cannot take place by natural secretion; an acutely inflammatory process is instituted. By the depressing agency of the poison, typhoid symptoms have been already induced; and the inflammation goes on to suppuration. Of the external circumstances favouring its occurrence, we also know but little. It may occur after an operation for phymosis, just as after amputation. In Table VI., it seems very frequent after primary amputations of the leg.

SECONDARY HÆMORRHAGE.—Modern surgery and modern care have reduced the mortality from this occurrence to a minimum. It is only recorded as cause of death in two cases, in the "Medical Times" of a year and a half (see Table III.)

It may be caused within a few hours of the operation from the detachment of the ligature, or from a vessel which, at the time, was not tied—or from sloughing of the wound opening unclosed vessels, at a later period—or, later still, from ulceration of the arterial coat at the time of the spontaneous separation of the ligature.

AFFECTIONS OF STUMPS.—These affections, painful though they be, have apparently but a small share in the mortality. The most painful affection of stumps is that produced by the impaction of a nerve therein; but protrusion of bone has been the cause of much suffering and exhaustion.

One example of death from *tetanus* is recorded in Table VII. *Hospital gangrene* has been, at different times, according as it has been prevalent, the cause of many deaths.

It now only remains, before conclusion, for me to consider some of those external circumstances which are supposed to influence the rate of mortality after amputation.

Crowded Hospitals.—In such, general debility and irritability are common. Hæmorrhages, from the surface of an irritable stump, are frequent. Says Mr. Guthrie:—"If the state of the stump, in any case, depend on the bad air of the hospital, the patient had better be exposed to the inclemency of the weather than allowed to remain."

Zymotic Influences.—According to Guthrie, where febrile diseases are endemic, purulent deposits often prevail, constitutional irritation is great, the stumps do not unite, or, if united, open out and slough, and frequently implicate the veins.

After amputation, patients are frequently prone to prevailing fevers. After the battle of Waterloo, the wounded of one regiment were sent some to Brussels and some to Antwerp. The former suffered, after amputation, principally from inflammatory fever—the latter from an endemic fever then prevalent at Antwerp, and peculiar in commencing as an intermittent and ending as typhus.

TREATMENT AFTER THE OPERATION.—There seems yet to be

too much opposition to that system which would support the vital powers.

In Paris lately, nearly half the cases were fatal. They do not stimulate, and their hospitals are too crowded.

Each coming year may we see a diminution in the rate of "Mortality after the Operations of Amputation;" and know more of, and be more powerful to countervail, "the Causes of that Mortality."

ADDENDUM.

TABLE

Showing the Mortality per cent. after Amputations for Diseases of Bones and Joints.

PRE-CHLOROFORM PERIOD.	ALL MEMBERS.	THIGH.	LEG.	UPPER EXTREMITY.
1837—42	33	29	44	23
1840	34	43	25	40
POST-CHLOROFORM PERIOD.	—	—	—	—
January, 1856, to July, 1857	19	20	17	14
1854 and 1855.....	20	20	23	8

The reader is requested, by means of this Table, to correct the numbers on page 17, lines 10—20.